NAVSTAR Global Positioning System

General Development Model (GDM) Phase II

Rockwell-Collins, Cedar Rapids, Iowa

GPS2-170

Noise Temperature Model for Wideband AGC Amplifiers

Steve F. Russell

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Abstract: A presentation of the Friis equation and the noise temperature model for the wideband, low-noise receiver used for the GDM model.

Internal Letter

Rockwell International

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TO L. W. Pinkston

Address 107-142

FROM S. F. Russell

Address 107-142

Phone 3136

cc: G. L. Bjornsen 107-142
J. W. Murphy 107-142
W. M. Hutchinson 107-142
R. W. Carroll 107-142
K. L. Brown 106-184
T. O. Perkins 107-142
D. K. Vail 107-142
G. W. Sellers 106-186

SUBJECT: Noise Temperature Model for Wideband AGC Amplifiers.

In recent discussions with Larry, I realized that there may be an issue concerning the design of wideband AGC stages and their effect on system noise temperature. Figure 1 shows a simple but adequate model of the effect of AGC on the effective noise temperature of a receiver.

Variations in the attenuator affect GPS signal and jammer signal equally and also have the effect of changing the equivalent receiver noise temperature thereby reducing the equivalent signal-to-thermal noise ratio. The effective receiver noise temperature is determined by applying the Friis equation to the model to give

$$T_r = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \frac{(L-1)}{G_1 G_2} (T_c + T_3)$$

where:

T_r = Effective Receiver Noise Temperature.

T_1 = Noise Temperature of First State.

T_2 = Noise Temperature of Second Stage.

T_3 = Effective Input Noise Temperature of the Third Stage.

T_c = Physical Noise Temperature of the Attenuator.

G_1 = Power Gain of First Stage.

G_2 = Power Gain of Second Stage.

L = Attenuation Factor ($1 \leq L \leq \infty$).

The last term in the equation above is the contribution to increased noise due to the attenuation effect. In a well designed receiver, the stage gains are usually chosen so that the second and third terms have a negligible contribution compared to T_1. For present purposes, it will be sufficient to compare the last term with T_1. As a general rule it is sufficient that:

$$\frac{(L-1)}{G_1 G_2}(T_c + T_3) \leq \frac{1}{10} T_1$$

Using the conversion equations given in Table 1 we can present the following numerical example:

FIRST STAGE

Gain = 13 dB	G_1 = 20
Noise Figure = 3.5 dB	T_1 = 359°K

SECOND STAGE

Gain = 25 dB	G_2 = 316
Noise Figure = 5.5 dB	T_2 = 739°C

Assume the temperature of the attenuator to be T_c = 290°K. The effective input noise temperature of the third and succeeding stages is:

$$T_3 = 1500\,°K \qquad (NF_3 = 7.9 \text{ dB})$$

The effective receiver noise temperature is calculated as follows:

$$T_r = 359°K + \frac{739°K}{20} + \frac{1500°K}{20 \cdot 316} + \frac{(L-1)}{20 \cdot 316}(290°K + 1500°K)$$

$$T_r = 396°K + (L-1)\,(0.2833)°K$$

To satisfy the general rule of sufficiency, the AGC controlled attenuation can be no larger than 21.5 dB (L = 141). In this example, the noise figure at full allowable attenuation is NF_n = 3.8 dB.

For an attenuation of 35 dB (L = 3162), the effective receiver noise temperature and noise figure become:

$$T_r = 1292\ °K$$

$$NF_r = 7.4 \text{ dB}$$

Although this simple discussion does not model the receiver design exactly, it does show the procedure for calculating the tradeoff between gain and AGC range to preserve receiver noise figure. Detailed calculations should be performed on the actual Phase II design to demonstrate the effect of AGC on noise figure.

Steve H. Russell

S. F. Russell
107-142

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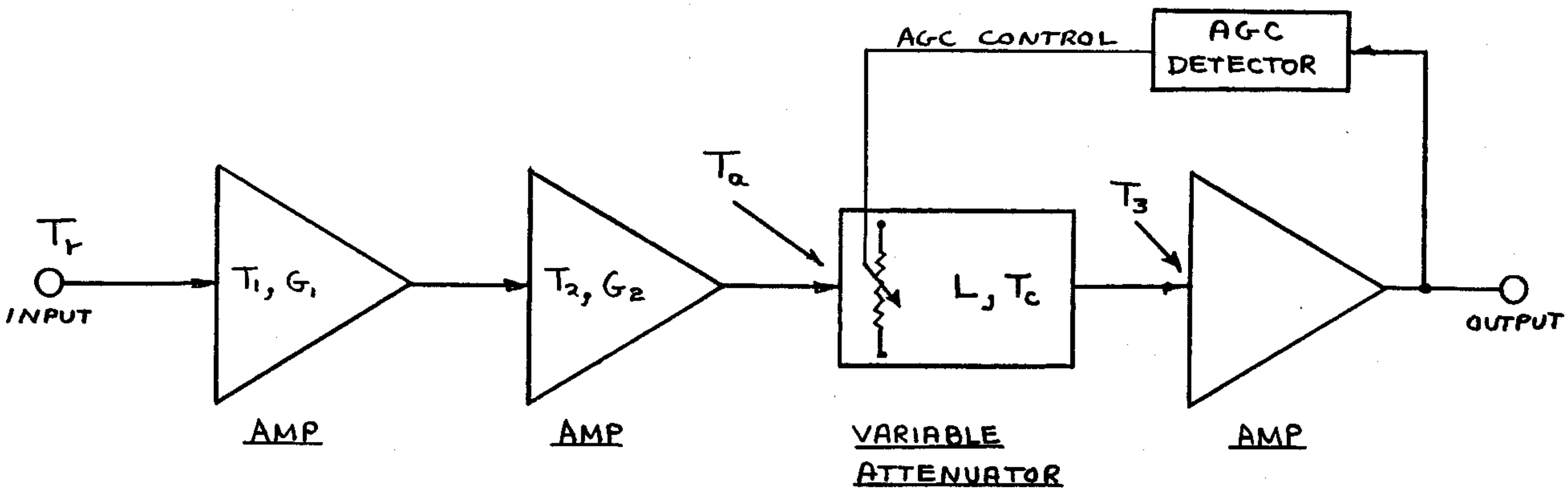

NOTES:

1. G = GAIN
2. T = NOISE TEMPERATURE
3. L = ATTENUATOR LOSS

FIGURE 1. Noise Temperature Model for a Wideband AGC Amplifier.

TABLE 1. Conversion Equations Among Noise Temperature, Noise Factor, and Noise Figure.

	T_n	F_n	NF_n
T_n (°K)	—	$= T_o(F_n - 1)$	$= T_o\left(10^{\frac{NF_n}{10}} - 1\right)$
F_n	$= 1 + \frac{T_n}{T_o}$	—	$= 10^{\frac{NF_n}{10}}$
NF_n (dB)	$= 10 \log\left[1 + \frac{T_n}{T_o}\right]$	$= 10 \log F_n$	—

NOTES:

1. $T_o = 290\,°K$
2. $F_n \geq 1$
3. $T_n \geq 0$